THE ASSOCIATED GROWTH OF LEGUMES AND NON-LEGUMES

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INTRODUCTION

The advantage sometimes derived by a non-leguminous crop from a leguminous crop growing with it was recognized by the ancients. According to King the Chinese have for centuries grown soy beans, Chinese clover, and other legumes with barley, millet, and maize. "If plants are mutually helpful through close association of their root systems in the soil, as some believe may be the case," he observes, "this growing of different species in close juxtaposition would seem to provide the opportunity".^a Columella^b mentions the growing of mixtures of legumes and non-legumes by Roman farmers, also.

Several such mixtures are mentioned in the essays of Jethro Tull,^c an English farmer of the early eighteenth century. He noted the beneficial effect of clover and sainfoin on cereal crops on poor soil. Dickson, another Englishman, in his Practical Agriculture (1805)^d refers to several of them also, and states that clover sown with oats or barley in the spring is apt to cause the grain crop to lodge. Hine (1849)^e alludes to mixtures of sainfoin with oats, bar-

a - King, Farmers of Forty Centuries, p. 10.

b - Daubeney, Lectures on Roman Husbandry, Oxford 1857, p.253.

c - Tull, Horse-hoeing Husbandry (edited by Wm. Cobbett).

d - Dickson, Practical Agriculture, or A Complete System of Modern Husbandry, London, 1805.

e - Journal of Agricultural Society X (1849), p. 54.

ley, and wheat, as commonplace. The influence of the legume on the non-legume associated with it was clearly recognized by Nathusius,^a a Prussian, who wrote in 1859 "It is really wonderful to see how the poorest land, which scarcely used to grow a few annual grass plants, in the shade of the luxuriant lupines is immediately covered with different weeds". Storer's Agricultural Chemistry,^b published in 1887, contains the statement "Grasses may get some good from the secretion of the micro-organisms which the clover supports".

The nature and effects of the interactions of such crops grown in mixture are of much scientific interest and practical importance. Is the increased development due merely to the better utilization of space, light, and soil nutrients by plants of different structure? Is it peculiar to legume and non-legume mixtures? Is the development of either crop necessarily retarded by that of the other? Is nitrogen made available to the non-legume in any way by the legume? If so, how is this brought about? Do the roots of the legume excrete a nitrogenous substance available to the non-legume? Do they stimulate nitrification? Or do they by their own decomposition increase the nitrogen supply? What is the effect on the proportion of nitrogen in the crops? On the yield of nitrogen per area unit? If it should be found that the yield or nitrogen content of the non-legume is

a - Journal of Agricultural Society XX (1859) p. 107.

b - Storer, Agricultural Chemistry, 1887, p. 539.

much increased, important practical results may follow. In some crops, such as corn for ensilage or "hogging off" and grass for pasture or hay, the presence of the legume would be an advantage if the yield were not considerably reduced; while in others, such as the cereals, it would be a disadvantage unless the yield were considerably increased. The most favorable methods of culture under field conditions should be worked out for those crops which offer possibilities of profitable combination.

There are thus two principal phases of the problem for investigation: the one concerned with the study of the mechanism of interaction between associated plants, and the other with the study of the practical possibilities of associated crops in the field.

Experimental Investigation

The first experimental investigation of this problem was reported by LaFlize (7) in 1892. Believing that a leguminous crop might supply enough nitrogen to support a cereal crop on a poor soil, he seeded crimson clover with rye on a very poor two-acre field at the Rambouillet experiment farm in France. The field was fertilized with potassium, phosphorus, and calcium, but not with nitrogen. The yields were good and the rye reached a height of six feet. For four years thereafter he grew barley, peas, and vetch on the same field, and obtained each year a very satisfactory yield of both legume and non-legume. From his re-

sults he concluded: "Que les cereales semmees avec les legumineuses, vivant en symbiose avec elles, s'emparent de l'azote fixe par les bacteries et que cette nitrification du sol est assez puissante pour donner, conjointement avec elles, une recolte moyenne de grains sans addition d'azote etranger." Strebel (1897) (24) found that clover increased the yield of both an accompanying and a following crop of grain.

Nobbe and Richter (1902) (19) in a study of the effect of nitrogen on the inoculation of leguminous plants, grew oats and soy beans in pure and mixed culture in pots; and found that the effectiveness of inoculation on the yield of beans was decreased by the presence of nitrogen in organic or inorganic form, and was increased by the growth of oats with the crop. They concluded that the increased effectiveness of inoculation in the presence of the oats was caused by the removal of nitrogen by the latter. The pure cultures of oats and soy beans were planted at the rate of ten plants per pot and the mixed cultures at the rate of five plants of soy beans and five of oats per pot. They were grown in a humus-rich soil and in a mixture of this soil with sand. The latter medium was used unfertilized and fertilized with 500 and 1000 milligrams of nitrogen in the form of potassium nitrate. The data show the following facts of interest in the study of associated growth:

Oats yielded somewhat more per plant, but considerably less per area unit when grown with beans. The gain in yield of oats from association was greater in pots not inoculated

in the poor soil and in the mixed soil heavily fertilized. In the mixed soil lightly fertilized it was about the same, and in the unfertilized mixed soil it was greater in inoculated pots. The yield of uninoculated beans was greatly increased by the addition of nitrogen, while that of inoculated beans was hardly affected. Beans grown with oats yielded more per plant than beans grown alone when inoculated, but less when not inoculated. In rich soil the yield of beans per plant was not much increased by association when the beans were inoculated, and when they were not inoculated it was somewhat decreased.

In considering these results, it should be remembered that, aside from the possible effects of association itself, some difference in the yield per plant in pure and mixed culture is to be expected on account of the reduced rate of planting of both crops when grown in mixture. For instance, if the peas do not require nitrogen for growth, each of the five oat plants in the pot growing the mixed culture would have twice as much nitrogen at its disposal as one of the ten oat plants in the pot growing oats alone. This probably accounts for the higher yield of oats per plant in the mixed culture. The bean plants when inoculated profited similarly from the association, but when not inoculated they were seemingly unable to compete favorably with the oat plants for nitrogen, and yielded less per plant than when grown in competition with larger numbers of their own kind. A significant feature of these data is the fact

that the benefit from association in nitrogen poor soil is seemingly dependent upon inoculation. This indicates that the nitrogen supply of the non-legume may be in some way increased by the presence of the legume.

Lyon and Bizzell (1909) (11) noted that the weed Eri-
geron annuus growing with alfalfa apparently shared the good or poor condition of the alfalfa caused by lack or abundance of lime, and found that its nitrogen content fluctuated with that of the alfalfa, increasing with the basicity of the soil. Samples of timothy hay grown alone and in association with alfalfa were found to have increased in nitrogen content when grown with the legume, whether on limed or on unlimed soil. The report concludes, "A possible improvement in the nitrogen content of certain plants by growing them with legumes is indicated." A year later the same investigators reported an increase in the percentage of protein in timothy grown with alfalfa or red clover, and oats grown with peas, in field mixtures. The following table gives the nitrogen content of these crops grown alone and in association with a legume.

Crop	Per cent Nitrogen in Dry Matter
Timothy alone	2.04
Timothy grown with alfalfa	2.49
Timothy alone	1.44
Timothy grown with alfalfa	1.55
Timothy grown alone	2.75
Timothy grown with clover	3.93
Oats grown alone	2.03
Oats grown with peas	2.15
Oats grown alone	2.39
Oats grown with peas	2.59

The non-legume was seeded at the same rate whether in mixture or pure culture. The yields of hay from the plots of mixed peas and oats were 3750 and 4850, and from the corresponding plots of oats alone 2900 and 3900, respectively. The yields of the other crops are not given.

Soil on which alfalfa had grown for five years was found to contain a higher content of nitrates than soil on which timothy had grown five years, and also to have a higher rate of nitrification of ammonium sulphate. The authors state, "The higher protein content of non-legumes growing with legumes than of non-legumes growing alone is probably due to the more active nitrification caused by the presence of the legume." The nitrifying power of a soil which had grown alfalfa for five years and was then kept bare for a summer was greater than that of adjacent plots on which timothy had been grown for the same length of time, and which had likewise been kept bare for a summer, indicating, in the opinion of the authors, "a benefit arising from the influence of a legume on the rate at which nitrification goes on in the soil, even after a crop has been removed."

But the increased proportion of nitrogen in a non-legume when grown with a legume is not proof that nitrogen was supplied to it by the latter. The nitrogen percentage is influenced by other factors. For example, the nitrogen percentage steadily decreases as the crop advances toward maturity, though the absolute nitrogen content increases. Withholding water from the plant increases

the percentage of nitrogen also as has been shown by Widtsoe^a and by Langer and Tollens.^b The timothy and oats of Lyon and Bizzell's experiments were seeded at the same rate whether a legume was grown with them or not. The supply of moisture available to the non-legume in the mixture may have been reduced by the thicker seeding and the nitrogen percentage thereby increased. It is probable also that growth was retarded and that the plants in the mixtures, though cut the same day, were not as far advanced as those grown alone, and therefore contained a higher percentage of nitrogen. Determinations of the absolute as well as the relative amounts of nitrogen produced are necessary in comparisons of this kind.

Lyon and Bizzell also claim that they have shown "that the growth of a legume caused the soil to nitrify more rapidly than did the growth of a non-legume thus leaving a larger quantity of readily available nitrogen at the disposal of the timothy plants in the soil on which alfalfa grew with the timothy." The increased protein percentage of the timothy might be explained on this basis, as it is well known that the nitrogen content of plants may be increased by the increase of soil nitrates. But as Lipman has pointed out, the alfalfa and timothy fields from which samples for nitrate determinations were drawn

a - Widtsoe, J. A. Jour. Amer. Soc. Chem. 25, 12: 1234-1243.

b - Langer, L. and Tollens, B. Jour. Landw., 49, 3: 209-229.

were nearly five years old. The soil under alfalfa had possibly accumulated a larger quantity of nitrifiable material than that under timothy, and thus gave a greater amount of nitrates. If the greater stimulus to nitrification from the growth of alfalfa is caused merely by the greater accumulation of its decaying roots, it could hardly be expected to be of much assistance to a non-leguminous crop growing with it the first year.

Lipman in 1912 (10) reported results of cylinder, pot, box, and field experiments with oats and peas, corn and cowpeas, rye and vetch, barley and clover, barley and vetch, corn and soy beans, wheat and crimson clover, millet and alsike clover, and barley and crimson clover.

The cylinders used were of galvanized iron, open at both ends, 4 feet deep, and 23 inches in diameter. They were sunk in the ground and filled to within 10 inches of the top with subsoil material consisting of sand and gravel. To this was added 200 pounds of sandy surface soil, deficient in organic matter and nitrogen. Each was fertilized with 225 grams of ground limestone, 30 grams of acid phosphate, and 15 grams of potassium sulphate. Two were seeded with 100 seed of oats, two with 30 seed of peas, and two with 50 of oats and 15 of peas each. The series was repeated with six more pots, to each of which 10 grams of sodium nitrate was added. The table below shows the amounts of nitrogen produced. For either crop alone the figure given is the average of the two duplicate cylinders; for

the mixed crop it is the sum of the two. Thus the comparison is between two pots seeded with 100 seed of oats and 30 seed of peas in mixture and two identical pots seeded with the same number of seed in pure culture.

Without Nitrogen Fertilization	Milligrams of Nitrogen in Crop	
	Oats	Peas
Oats alone	792.5	
Peas alone		1813.5
Mixture	1234	2210
With Nitrogen Fertilization		
Oats alone	1792.5	
Peas alone		2220.5
Mixture	3382	1516

From these results Lipman drew the following conclusions:

1. Under favorable moisture conditions, oats growing together with Canada field peas may secure large amounts of nitrogen from the latter, even though this may not be indicated by an increased proportion of nitrogen in the dry matter of the oats.

2. The presence of the oats in such mixed seed-ing need not decrease the yields of dry matter and of nitrogen in the peas.

3. When sodium nitrate is applied to such crop mixtures, the oats gain an advantage in the competi-tion for moisture, light and plant-food, and the growth of the peas is depressed. They then contain

not only less of the dry matter and nitrogen, but may possess a smaller proportion of nitrogen in the dry matter.

4. The presence of sodium nitrate may depress nitrogen fixation by the Canada field peas.

The experiment was repeated with corn and cowpeas with analogous results.

Lipman's claim that oats grown with Canada field peas may secure large amounts of nitrogen from them, is based on the higher yield per plant of oats grown in the mixture. But the oats in the mixture were planted at the rate of 50 per cylinder, while those in the pure culture were planted at double that rate. The fact that the mixed culture cylinder contained 50 pea plants in addition to the 50 oats plants, does not mean that the latter had the same amount of nitrogen available to them per plant as the 100 oats plants grown alone. We do not know that the pea plants removed any nitrogen whatever from the soil, and it seems quite likely that considerably more than half as much nitrogen was available to the 50 oats plants in mixed culture, than was available to the 100 in the pure culture. The increased yield of nitrogen per oats plant in the mixed growth might well be due to the larger amount of soil nitrogen available without regard to the effect of the peas, unless the oats in the mixture produced an absolutely higher yield per cylinder when grown with peas than when grown alone. They did not do this in the experiments cited above. The second conclusion also

must be modified when considered from this standpoint, but it is of little importance in the present study.

The pot experiments were designed to determine whether the nitrogen supposedly obtained by the non-legume from the legume is diffused in soluble form from the roots of the latter. The non-legume was grown in a small pot of porous earthenware, which was placed in a larger pot in which the legume was grown. Thus the two crops were separated by a membrane permeable to water and dissolved substances, but not to roots. Oats and peas and rye and vetch were grown in duplicate in pots as described. In addition, checks in which the inner pots were glazed were provided. The soil was a white quartz sand, fertilized with finely ground oyster shells and nutrient salts. The amount of nitrogen produced in each case is shown in the following table.

No.	Inner Pot	<u>OATS</u>	<u>PEAS</u>
		<u>N</u> (Milligrams)	<u>N</u> (Milligrams)
1	Glazed	42.6	781.2
2	"	22.0	304.3
3	Unglazed	346.4	939.25
4	"	32.2	360.0
		<u>RYE</u>	<u>VETCH</u>
5	Glazed	16.0	682.5
6	"	19.0	193.8
7	Unglazed	104.0	540.8
8	"	27.2	634.8

From these results Lipman concluded that soluble nitrogen compounds may diffuse out of the roots of the legume and be taken up by the roots of the non-legume. He explained the discrepancy between duplicates by differences in the porosity of the inner pots and the inoculation of the legumes. Whatever the explanation of these discrepancies, they surely indicate an experimental error far too great to permit drawing any conclusions from the test.

Similar pot experiments were performed with clover and barley. In one case clover was grown in both inner and outer pots, in another clover in the inner and barley in the outer, in another barley in the inner and clover in the outer, and in another barley in both. Both glazed and unglazed inner pots were used. The yields in the inner pots, whatever the crop, were invariably greater in unglazed than in glazed pots, and conversely the yields in the outer pots were greater whenever the inner pots were glazed. Obviously the moisture distribution was disadvantageous to the plants in the inner pots, which made good growth only when in pots which permitted the entrance of moisture from without. Here again the experimental error vitiates the results.

Aside from these experimental errors the pot method as used by Lipman is inadequate. Any nitrogen available to the plant, whether derived from decomposing roots, increased bacterial action, or whatever source, could diffuse through the porous pot exactly as a soluble root excretion

could, for it would have to be in soluble form before it could be used by the plant.

In the greenhouse box experiments eight metal boxes, each divided in the middle by a porous stone slab cemented to the bottom and sides, were used. Each contained 48 pounds of white quartz sand, 2 pounds of fertile soil, and 6 grams of acid phosphate, 4 grams potassium sulphate, 15 grams magnesian air-slacked lime, and 0.2 gram ferric sulphate. In four of the boxes a non-legume was grown in one half and nothing in the other. In the other four the non-legume was grown in one half with a legume in the other. The non-legume in almost every case made better growth and contained a higher proportion of nitrogen when the legume was not grown in the other half of the box. The results are discarded by Lipman with the observation that moisture rather than nitrogen became the limiting factor of growth.

Another greenhouse experiment involved the growing of oats and peas in pure and mixed culture in jars containing (1) 20 pounds of white sand, (2) 19 pounds of sand and 1 pound of soil, (3) 15 pounds of sand and 5 pounds of soil, (4) 10 pounds of sand and 10 pounds of soil, and (5) 20 pounds of soil. Soil infusion and the usual fertilizer (containing no nitrogen) were added. Optimum moisture conditions were maintained. The yield of oats grown alone or in mixture gradually rose as the proportion of soil was increased. The yield of peas in both cases was almost constant. This is consistent with the results of nitrogen

fertilization in the cylinder experiments if we consider the effects of the soil to be caused by the soil nitrogen. The percentage of nitrogen in the oats also increased while that in the peas was but slightly affected. From these facts Lipman concludes, "the increasing amounts of nitrogen contributed by the soil not only lead to greater yields of dry matter, but also to a relatively higher content of nitrogen in the latter (the non-legume)." The increase in the nitrogen percentage of the oats caused by the association of the legume was most marked in the sand culture. Lipman comments, "now from the standpoint of the present experiment it is important to note that the differences are very marked in the sand, but since the latter could not furnish any appreciable amount of nitrogen to the crop, there is an indication at least that the legume contributed some nitrogen to the growth of the non-legume." However, the oats in the mixed culture produced only 1.2 grams of dry matter per pot, while the oats in the pure culture produced 3 grams in one pot and 3.5 in the other. It is possible (in fact, highly probable) that the increase in the percentage of nitrogen was caused by the retardation of growth. (See page 8 of this paper.) At any rate Lipman's conclusion is drawn from determinations of the relative content of nitrogen without regard to the absolute content, and he thus falls into the very error of interpretation he pointed out as fatal to the conclusions of Lyon and Bizzell.

The field experiments of Lipman were designed to show that non-legumes may derive a portion of their nitrogen

supply from legumes with which they are associated. They failed in this purpose because of the intervention of factors other than the nitrogen supply, which became the limiting factors of production. Mixtures of corn and cowpeas and corn and soy beans were apparently more adversely affected by lack of moisture than either of the crops grown alone, and the author concluded that the increased draft on the soil moisture caused by the cowpeas overbalanced any possible benefit that may have accrued through their presence. The total dry matter and total nitrogen produced by the mixed crop were sometimes greater and sometimes less than those of the more productive component grown alone. Oats and peas were also tested in the field, the pure cultures of each being seeded at the rate of 3 bushels per acre and the mixtures at the rate of $1\frac{1}{2}$ bushels of each. In one case the mixture produced 70 pounds of dry matter containing 1.493 pounds of nitrogen, while an equal area of oats alone produced 50 pounds of dry matter containing .577 pounds of nitrogen, and an equal area of peas 50 pounds of dry matter containing 1.405 pounds of nitrogen. In the other two cases the yield of nitrogen in the mixture was about equal to the average between the amount produced by the oats and the amount produced by the peas. The phase of the problem studied by Lipman is not well suited to field study on account of the difficulty of controlling the moisture and the chemical and physical composition of the soil. This fact he recognized and his conclusions are

not dependent on the results of his field experiments. His conclusions are as follows:

"1. Under favorable conditions non-legumes associated with legumes may secure large amounts of nitrogen from the latter, even though this may not be indicated by an increased proportion of nitrogen in the dry matter of the non-legume.

"2. The presence of the non-legume in the mixed growth need not decrease the yields of dry matter and nitrogen in the legume.

"3. When sodium nitrate is applied to such crop mixtures, the non-legumes gain an advantage in the competition for moisture, light, and plant-food, and the growth of the legume is depressed. The latter contains then not only less of dry matter and nitrogen, but may possess a smaller proportion of nitrogen in the dry matter.

"4. The presence of large amounts of sodium nitrate tends to depress nitrogen fixation by legumes in mixed or unmixed growths.

"5. It seems probable that nitrogen compounds pass out of the roots of at least some legumes, and that such nitrogen compounds may become available to the non-legumes in mixed growths.

"6. When legumes and non-legumes are grown together, the relative yields of the two are intimately affected by the amount of available nitrogen compounds in the soil. Everything else being equal, the greater the amount of combined nitrogen placed at the disposal of the mixed crop,

the greater the relative yield of the non-legume, and the smaller the relative yield of the legume.

"7. In the associative growth of legumes and non-legumes the development of the latter may be depressed rather than enhanced when factors other than the supply of combined nitrogen limit production.

"8. The mere determination of the proportion of nitrogen in non-legumes grown alone and in association with legumes is not adequate for demonstrating that the latter supply nitrogen compounds to the non-legumes associated with them."

The really significant conclusions, the first and fifth, are based on unsound data and must be discarded. Lipman's results strongly indicate a benefit to the non-legume caused by association with the legume, but they do not prove it. They establish nothing regarding the mechanism of the assumed benefit.

Pilz, an Austrian investigator (1911) (20) conducted pot and field experiments with mixtures of oats and vetch and peas and barley. In the pot experiments a loose, fine-grained limestone clay soil, rich in plant food, was used. Some of the pots were not fertilized, some were fertilized only with mineral nutrients, and some were given a complete fertilizer treatment. The plants were seeded thickly, and in all cases thinned to 25 of barley and 13 of peas, or 25 of oats and 16 of vetch. Thus the mixed cultures were seeded at double the rate of pure cultures. In the field

experiments the crops were planted singly at a low and a high rate and were then combined, the low rate of one with the high rate of the other, and vice versa. In this case also, therefore, the seeding in the mixed cultures was twice as thick as that in the pure cultures with which they were compared. The results of the pot and field experiments were consistent and may be summarized as follows:

The yield of dry matter in mixtures was consistently higher in proportion to the area and lower in proportion to the number of plants than that in pure cultures. The yield of dry matter in pure cultures was more influenced by fertilizing than that in mixed growths. In mixed cultures the legume contained less nitrogen and the grass more than in pure cultures, except that in especially poor growth of the legume, or in the presence of an abundance of nitrogen, the legume sometimes yielded a higher content of nitrogen. The nitrogen production per area unit was greater in the mixed culture than in the corresponding pure cultures. Fertilization apparently had more effect on the nitrogen content of plants grown in pure cultures than on that of plants grown in mixtures. The increased nitrogen content of the grass in the mixed growths is considered by Pilz to be the result of its arrested development. The fall in nitrogen content of the legume he explained as due to reduced symbiosis in the roots caused by crowded conditions.

Kellerman and Wright (1914) (5) found that in mixed

growths of peas and barley and beans and barley in unfertilized loam soil, in paraffin baskets, both crops contained more total nitrogen than in pure cultures. The yields were reported only in graphic form, but were approximately as follows:

Crop	Milligrams of Nitrogen
Beans alone	62
Peas alone	69
Beans with barley	99
Peas with barley	72
Barley with beans	38
Barley with peas	37
Barley alone	21

The rate of planting was not reported.

Westgate and Oakley (1914) (26) found that in 19 samples of non-legumes grown with legumes on various soil types in several parts of the country, the nitrogen content was increased in ten cases and decreased in nine. The variation in nitrogen content ranged from an increase of 2.02% to a decrease of 2.61%.

Ellett, Hill, and Harris (1915) (2) tested the effect of white clover, red clover, and beans, on bluegrass, timothy, and corn respectively, under greenhouse conditions. The legume and non-legume were grown together in one plat, while on one side the non-legume was grown alone separated from the mixed growth plat by a four inch concrete wall, and on the other the non-legume was grown alone separated from it

only by four inches of vacant soil. The soil used was a layer of Hagerstown loam ten inches deep, underlaid with a fourteen inch layer of coal ashes. The variations were for the most part irregular and the uneven stands obtained could well account for larger variations regardless of the effects of association. Only in the case of the corn and beans is there a marked difference.

	D. M. pounds	Nitrogen %
Corn alone, separated by concrete wall	4.25	1.73
Corn grown with beans	8.00	2.05
Corn alone, separated by soil	6.50	1.63

The number of plants is not given but must have been very small in the case of the corn and beans for the plats were only about four feet square. Individual variation between plants may account for the variation shown above.

Evans (1916) (3) found the percentage of protein in the green leaves of timothy, redtop, and Kentucky bluegrass increased by growth with clover in thirty of the thirty-one cases tested. The length of leaf of the grasses grown in mixture with the legume was invariably found to be greater and the proportion of dry, brown leaves smaller.

The experiments so far discussed have been concerned primarily with the discovery and study of the mechanism of the interactions of associated plants. The use of legume and non-legume mixtures in actual farming is dependent upon many practical considerations which can best be tested in

field experiments. A number of field trials of such mixtures have been made with the one object of testing their value for practical and immediate use. Gettys (1900) (4) highly recommended cowpeas and corn grown together for ensilage, the corn to be drilled 9 to 16 inches apart in rows $4\frac{1}{2}$ feet apart, and the peas to be planted after the first cultivation, in rows as close as possible to the corn row so as to permit the use of the corn harvester. He claimed that the total yield of forage was increased and the quality of the ensilage much improved by the increased content of nitrogen. Neale (1901) (16) in a number of extensive cooperative tests in Delaware, found this system profitable and recommended it to the farmers of that state. The total yield was slightly reduced but the protein content was increased twenty-five per cent.

Lindsey (1901) (8) recommended several leguminous mixtures for forage in Massachusetts, including wheat and vetch, grasses and clover, oats and peas, millet and peas, corn and soy beans, and barley and peas. He advised seeding a mixture of ten quarts of corn and seven quarts of soy beans for forage. C. L. Newman (1901) (17) at the Arkansas Station sowed cowpeas broadcast at the rate of one-half bushel per acre, in two plots of corn at the last cultivation, and drilled at the same rate and time in two plots, and left two plots adjacent to each without cowpeas for comparison. The following table shows the yield of corn and of cowpea hay and seed, and also the yield of corn the year following, when all of

the plots were seeded to corn alone.

Plots	1899 Bu.corn	1899 Bu.peas	1899 Lb.hay	1900 Bu.corn
1 & 5 No peas	24.8			18.4
2 & 6 Peas drilled	23.7	11.42	1498	20.9
3 & 7 Peas broadcast	22.4	6.14	1264	22.0
4 & 8 No peas	23.1			18.1

J. S. Newman (1901) (18) in South Carolina, found the yield of corn materially increased when cowpeas were grown between the rows. The increase was greater where the peas were sown broadcast than where they were drilled. "The experiments were conducted on alluvial river bottom, which was reclaimed from Bermuda grass and underdrained in 1892. Its productiveness was increased by tillage and peas from 25 bushels per acre to the yields here reported in '98 and '99 (70-80 bushels per acre with the preferred methods) Owing to the moisture and fertility of the soil the effects of different methods of planting and cultivating were not pronounced." In the same year Soule and Vanatter, (22) at the Tennessee station, compared barley, oats, wheat, and vetch, oats and vetch, and wheat, oats, and vetch for hay. The wheat and vetch, seeded at the rate of $1\frac{1}{2}$ bushels of wheat and 1 bushel of vetch, gave the highest yield, slightly surpassing the wheat alone, seeded at the rate of two bushels per acre. Two bushels of oats seeded with one bushel of vetch yielded slightly less than three bushels

of oats seeded alone. The yield of vetch alone was not reported.

Six years later the same workers, (23) now at the Virginia station, compared oats and vetch seeded at several rates (from 16 pounds of vetch and 25 pounds of oats to 48 pounds of vetch and 50 pounds of oats), with oats alone seeded at the rate of 50 pounds per acre. The yields in tons per acre were:

Oats alone	1.32
Average of all combinations	1.25
Highest yielding combination (vetch 16, oats 37½)	1.57

In all cases the proportion of vetch was small, and the authors concluded it was not well adapted to the locality.

Scott (1908) (21) got almost as large yields from four rows of velvet beans eight feet apart, with rows of corn between, as he got from eight rows of velvet beans alone four feet apart, with similar (not the same) fertilizer treatment. The corn yielded 10-15 bushels. No yields are given for velvet beans grown alone in rows eight feet apart or for corn grown alone.

Buichikhin (1907) (1) found that growing alfalfa, clover, and sainfoin under summer cereals in the Russian steppes region did not increase the yield of the cereal crops, and gave as the reason that perennial leguminous crops draw too much moisture from the soil.

Ten Eyck and Call (1909) (25) recommended growing cowpeas with corn for silage in Kansas. The seed should

be mixed in even proportions by weight, and planted at such a rate that the corn plants will be eighteen inches and the cowpea plants four to six inches apart in the drill row. When sown at the last cultivation the cowpeas should be planted in two or three rows between the corn rows with a one-horse drill. Corn with cowpeas sown between the rows at the last cultivation gave an average yield of 47.62 bushels for five years, while corn alone yielded 43.98. In the particularly dry season of 1906 the corn alone yielded 4.28 bushels more than the corn grown with the cowpeas, but in every other season the latter was superior.

Miller and LeClair (1915) (14) found that a combination of cowpeas and corn did not seriously exhaust soil moisture, though it used more than corn alone. The height of corn plants was reduced about a foot by the presence of the peas and the yield was slightly reduced.

In Nebraska Kiesselbach (1915) (6) found the yield of silage from corn grown alone and corn grown with soy beans practically equal. The corn was drilled fourteen inches apart in the row, and the soy beans drilled in the same row six inches apart.

General Considerations and Suggestions for Further Work.

The experiments of Nobbe and Richter cited on page 5 indicated that a non-legume could be benefitted by the association of a legume, that the benefit was in some way dependent on the inoculation of the legume, and that the presence of available nitrogen in the soil diminished the beneficial effect of association. An actual benefit was not definitely shown, however, either in this work or in any of the work which followed. The elaborate experiments of Lipman and Pilz supported these indications but did not advance the knowledge of the subject. A benefit to the legume also was indicated in the work of Kellerman and Wright.

When two crops grown in mixture are sown each at half the normal rate, as in the experiments of Nobbe and Richter and Lipman, some of the results are apt to be due not to association itself but to the changed conditions of competition. The pea and the oats plant, for instance, are each more favored in competition with the other than with another plant of its own species, because of the differences in their structure and physiological needs. For instance, the penetration and spread of the roots of oats and peas are so different that the competition between an oats plant and a pea plant is probably less in proportion to the plant food taken up than that between two oats plants or two pea plants. Unquestionably some at least of the increase in yield per plant found by Nobbe and Richter and by Lipman, should be

charged to such factors as this. This is a legitimate gain for associated growth. But the yields per plant can not be fairly compared when the plants are grown under conditions so different as in the experiments of these investigators. A similar gain takes place in many non-legume mixtures. It has been shown in combinations of cereals by Hays, Atkinson, Balentine, Zavitz, and others. The yield of the mixture was frequently found to be higher than the average of the yields of the components.

On the other hand, when two crops are seeded together each at the full normal rate, as in the experiments of Pilz, competition conditions are again seriously altered, for the rate of seeding in this case is double the normal. The influence is in the other direction, however, and an increased yield of the non-legume per plant obtained under these conditions would be acceptable proof that it was benefitted by the growth of a legume. Pilz found in every case a lower yield per plant in the mixtures. His higher yields per area unit can not be offered as proof of the beneficial effect of association for they may be entirely the result of the heavier seeding.

A benefit to a non-legume from the association of a legume would be clearly indicated by a higher yield of non-legume per plant in mixture when it was seeded at the same rate in both mixed and pure culture. The effect of the association would have to be powerful enough to outweigh the yield-reducing effect of the heavier seeding.

The latter, however, could be reduced to a minimum by light seeding and liberal provision of plant food. It has also been observed that the presence of available nitrogen apparently reduces the benefit of association. Nitrogen in the soil should therefore be reduced to a minimum. In the total absence of nitrogen the non-legume might not survive until it could obtain nitrogen from the legume, even if this were possible, but in the presence of just enough nitrogen to sustain it to this point, it should develop later with the aid of nitrogen obtained from the legume and should at maturity contain more nitrogen than was originally present in the soil and the seed. This would conclusively prove that nitrogen had been furnished to the non-legume by the legume, for the excess of nitrogen in the plant over that provided in the soil and seed could have come from no other source. If more than enough nitrogen is added the excess may overshadow the nitrogen actually obtained from the legume, if any. As there is no way to know exactly how much nitrogen is necessary to support the plant to the desired point, several series might be provided, the first with no nitrogen added, the second with a very small amount, the third with somewhat more, and so forth. Each series should include a pot with non-leguminous plants alone and another with the same number of non-leguminous plants and a few leguminous plants also. The part played by inoculation in the phenomenon could be determined by including in each series one pot with non-leguminous plants and inoculated leguminous

plants, and one with non-leguminous plants and uninoculated leguminous plants. The medium should contain no nitrogen, but should be fertilized copiously with all other requisite plant nutrients. An analysis of the medium at the conclusion of the experiment would show the amount of nitrogen deposited in the soil by the growth of the different cultures. Using oats and peas, for example, the planting order would be as follows:

Pot No.	Seeding		Inoculated	Nitrogen Fertilization
	Oats	Peas		
1a	4	0	No	0
1b	4	2	Yes	0
1c	4	2	No	0
2a	4	0	No	25 mgs.
2b	4	2	Yes	25
2c	4	2	No	25
3a	4	0	No	50 mgs.
3b	4	2	Yes	50
3c	4	2	No	50
4a	4	0	No	75 mgs.
4b	4	2	Yes	75
4c	4	2	No	75
5a	4	0	No	100 mgs.
5b	4	2	Yes	100
5c	4	2	No	100

If the non-leguminous crop is benefitted by the association with the legume, what is the cause of the benefit?

Several causes may be concerned. A mutual stimulation of the roots of different plants in the soil has been suggested by Lyon and Bizzell, Dandeno, and others. Lyon and Bizzell found in several cases a larger yield of different crops grown in pots when grown with another crop than when grown alone, even though seeded at the same rate in both cases. The plants were grown in the presence of an abundant supply of plant food. The successful mixtures included legumes in some cases but in many cases did not. Dandeno obtained a much better growth of oats, barley, wheat, and flax in soil in greenhouse pots when underground shoots of Canada thistle were present than when they were not. A Norwegian publication^a states that spruce trees make good growth on waste areas only when their roots are in contact with those of mountain pine. Several explanations have been offered of the increased yield of non-legumes grown with legumes. Tacke believed it to be caused by a reduction of denitrification in the soil by the presence of the legume. Hiltner believed that in the neighborhood of the legume roots conditions were better for the development of free living nitrogen-fixing bacteria. Lipman stated that the increase was due to decomposition of the legume roots, to a stimulation of nitrifying organisms, or to the excretion of a soluble nitrogenous substance by the roots of the legume.

a - A nitrogen-gatherer among trees. Norsk. Landmandsblad, 22 (1903), No. 18, pp. 231-233. Abs. in E. S. R., 15 (1903-4), p. 780.

If in the experiment outlined above, a higher content of nitrogen were found in the oats grown with inoculated peas than was originally present in the seed and soil, it would be shown not only that the non-legume is benefitted by the presence of the legume, but that it is able during the association to assimilate nitrogen fixed by the aid of the legume. The benefit could not be due merely to a stimulation of the roots for no root stimulation could cause the non-legume to extract from the soil more nitrogen than the soil contained. It could not be due to a stimulation of nitrifying organisms or a reduction of denitrification for there would be no nitrifiable material present. It could not be due to changed conditions of competition, for the gain would be absolute, not relative. It could be caused only by the decay of the roots of the legume, the excretion of nitrogenous substances from the living roots, or the stimulation of free-living nitrogen-fixing organisms. By growing the crop mixture in sterilized soil inoculated in one case with Bacillus radicolica, in another with a free living nitrogen-fixing organism, and in the third with no organisms whatever, the effect of these three causes could be segregated. If as large a gain were found in the sterilized soils as in the unsterilized, it could not be caused by decay of roots for there would be little or no decay in the sterilized soil. It could then be caused only by the excretion of nitrogen or the stimulation of free-living nitrogen-fixing bacteria. Now if there were a gain in the

sterilized soils not inoculated with nitrogen-fixing bacteria, it could be caused only by a nitrogenous root excretion. If there were no gain here but a substantial gain in the soil inoculated with nitrogen-fixing organisms, it might be caused either by stimulation of the latter or by their own unaided action.

These suggestions are necessarily general, The exact line of attack must be determined by circumstances, but it should be possible by some procedure similar to that discussed above to obtain a much clearer idea than we now have of the nature of the interaction of associated plants.

The experiments of Lyon and Bizzell and of Evans have shown that substantial increases in the percentage content of nitrogen in non-legumes may be obtained in the field by growing them with legumes. The work of Westgate and Oakley shows that these increases are not common to all such mixtures. To determine what are the conditions that influence this feature, an extensive field study must be made. The increased percentage of nitrogen is not always accompanied by a decreased total yield, for in the peas and oats mixture of Lyon and Bizzell there was a substantial increase in both yield and nitrogen percentage of the peas when grown in mixture, and they were seeded at the same rate whether combined with a legume or not. The problem is an exceedingly complex one for field study and it would perhaps be well to precede the field study with a pot study of the comparative effects

of different combinations and of moisture and fertility conditions. When the range of the experiment has been thus limited, careful tests can be made in the field to determine the effects of different rates of seeding, soil conditions, etc.

Field experiments to determine the best methods of farm culture for various legume and non-legume mixtures, are extremely important but are little concerned with the phases of the problem discussed above. Whether or not there is an actual gain in a non-leguminous plant caused by a leguminous plant grown with it, there is an actual and very clear advantage in growing some legume and non-legume mixtures in ordinary farm practice. This advantage has been recognized for many years and several such mixtures are very common in our agriculture today. The value of peas and oats, bluegrass and white clover, and timothy and red clover is unquestionable. Cowpeas and soy beans are now frequently combined with cultivated non-leguminous crops such as corn, sorghum, and millet. Other combinations of legumes and non-legumes are not *rare*.

To make the most of these combinations each must be studied carefully and individually, for each is a problem in itself. A separate study of each crop mixture must be made also in every locality where it is likely to be of value, for though the principles underlying the effects of associated growth are undoubtedly the same, the effects in the field will vary widely with local conditions.

A Legume to Grow with Corn

In many ways a legume mixture with corn would be valuable. Thousands of tons of corn silage are produced every year in the Corn Belt. Corn silage is a valuable feed but it would be far more valuable if it contained more protein. Many farmers mix some leguminous crop with corn in filling the silo, with good results. Labor could be saved if the two were grown together and there is a possibility of increasing the yield and the percentage of nitrogen in the corn thereby. If it is worth while to grow cowpeas on two acres to ensilage with the corn grown on two acres, when the yields of green forage per acre are five tons of cowpeas and twelve tons of corn, then it will be more worth while to grow the two together on the four acres for silage if the combined yield is eight and a half tons per acre. Yet the yield of corn is considerably reduced. Again, a ton of corn and cowpea silage with a protein content of $2\frac{1}{2}\%$ is worth considerably more than a ton of pure corn silage with a protein content of 2%. If a farmer could raise a ton of corn and cowpea silage, consisting of 75% corn and 25% cowpeas, on the same amount of land and labor that he ordinarily used to raise a ton of corn silage, it would be profitable for him to do so, yet in the report of an experiment comparing the two the corn would be shown to have suffered a 25% decrease in yield. In corn grown for hogging off also, the low protein content is a disadvantage which must be overcome by the supplementary

feeding of nitrogenous concentrates. Hogs can be fattened very satisfactorily, however, in a field of corn and beans or peas without nitrogenous concentrates. In a field of corn raised for almost any purpose a leguminous crop would be an advantage if it did not greatly reduce the yield of corn. It is possible also that the effect on the soil is less severe in proportion to the amount of plant material removed.

Several practical field tests of corn and a legume have been reported. Most of these are concerned with a mixture of corn and cowpeas. Some report an increase in the yield of corn; some a slight decrease. There have undoubtedly been many experiments showing a larger decrease, which have not been reported. From the experiments of C. L. Newman and J. S. Newman, and especially from that of Ten Eyck and Call, it seems certain that cowpeas can be grown with corn without seriously decreasing the yield of corn, and the work of the last named investigators indicates strongly that the yield of corn may be actually increased by the association of the legume. In dry seasons the non-legume in the mixed growths seems always to be injured rather than benefitted by the presence of a legume. But when moisture is not the limiting factor it has frequently shown a benefit. The only work reported with a combination of corn and soy beans is that of Kiesselbach of Nebraska. In a one year test he found the yield of silage from corn grown alone and corn grown

with soy beans practically equal.

The value of a leguminous crop grown with corn is recognized by many farmers. Such mixtures are regularly grown on a number of Missouri farms, for silage especially. Inquiries concerning them are frequently received by the experiment station. They have received considerable attention from the agricultural press.* The popularity of these mixtures and the difference in cultural methods used show a need for their thorough investigation. The cowpea and soy bean crops are the only leguminous crops adapted to this part of the country, which could be conveniently grown with corn. Both are profitably grown in Missouri, the cowpea being better adapted to the southern part and the soy bean to the northern part.

The cowpea

The cowpea Vigna sinensis has been widely grown in the South for many years for forage and green manuring and its culture has extended recently to some extent into the northern States. It is a native of India and is said to have been introduced into this country from England by the Georgia colonists in 1734. It is an annual leguminous

*Schaut, I. O. in Country Gentleman, Feb. 19, 1916.

Van Pelt, H. G. in Kimball's Dairy Farmer, Mar. 15 and Aug. 15, 1916.

Justice, J. L. in Orange-Judd Farmer, May 13, 1916.

Tomlinson, W. D. in Ohio Farmer, May 20, 1916.

Beavers, J. C. in Breeders' Gazette, June 1, 1916.

plant of trailing habit. The blossoms range in color from white to purple and the seeds from white to black. The pods are 5 to 16 inches long and are usually straw colored at maturity. Its growth is indeterminate and the plants continue to set seed from late summer well into the fall.

The cowpea is grown for hay, soiling, silage, pasture, seed, and green manuring. The seed contains 20.5% protein, 60.2% carbohydrates, and 1.5% of fat; and the hay 14.2% protein, 63.8% carbohydrates, and 2.6% fat. The hay is palatable and is relished by all kinds of stock. The rank growth of the crop, however, makes the hay rather hard to cure.

Given a fair amount of moisture and good culture, cowpeas will grow on almost any common type of soil. They are best adapted to the more open soils. The cowpea is a rank feeder and frequently makes a satisfactory growth on soils too poor for almost any other crop. The seedbed for cowpeas should be prepared about as for corn. The crop is always planted in rows for seed production, but is usually drilled or sown broadcast for hay or green manuring. When planted in rows the plants should be two or three inches apart in rows three feet apart. Being a southern crop cowpeas are very sensitive to a cold soil and should never be planted before the seedbed is thoroughly warmed. When planted in rows they should be cultivated two or three times before blooming. For hay they are cut when the first pods and some of the leaves begin to turn yellow. Curing

is very difficult. For seed it is hard to determine satisfactorily the time for cutting, as there are blossoms, green pods, and ripe peas on the plants at the same time until frost. Where labor is cheap the peas are usually picked by hand as they ripen. When they must be cut all at once, it will be found best to harvest just before heavy frost when most of the pods are brown.

The soy bean

The soy bean Glycine hispida is also a native of the Orient. It has been grown in North Carolina for almost a hundred years, but has been considered generally important in this country only about fifteen. It is an upright, branching, annual legume, reaching normally a height of one to six feet. It produces a small, straw-colored pod containing two to four seeds. The seed pods are borne in clusters. The seeds mature at practically the same time. They are round or flattened and vary in color from yellow to black.

Soy beans are grown for grain, hay, pasture, silage, and green manuring, and the seed are used in the manufacture of several articles of commerce. The feeding value of soy bean seed and hay compared with several other feeds, is shown in the following table, compiled from Henry's Feeds and Feeding.

Feed	Digestible nutrients			
	Protein	Carbohy- drates	Fat	Nutritive Ratio
	%	%	%	%
Soy beans (grain)	29.1	23.3	14.6	1:2.2
Cowpeas "	16.8	54.9	1.1	1:3.4
Corn "	7.8	66.8	4.3	1:9.8
Cottonseed meal (choice)	35.8	23.2	8.0	1:1.1
Soy bean hay	10.6	40.9	1.2	1:4.1
Cowpea hay	9.2	39.3	1.3	1:4.5
Red clover hay	7.1	37.8	1.8	1:5.8
Alfalfa hay	10.5	40.5	0.9	1:4.0
Timothy hay	2.8	42.4	1.3	1:14.5
Soy bean silage	2.7	9.6	1.3	1:4.6
Cowpea silage	1.5	8.6	0.9	1:7.0
Corn silage	1.4	14.2	0.7	1:11.2

Soy beans will grow on any ordinary well drained soil. They are highly resistant to drought and heat. The seedbed is prepared as for corn or other cultivated crops. The crop should not be planted before the soil is warm and the best time is about ten days after corn planting time. When grown for seed, soy beans are planted at the rate of 20 to 30 pounds per acre in drilled rows 3 to 3½ feet apart. When grown for hay it is best to grow them in rows also, unless the land is almost free from weeds. On very clean land they may be broadcasted or drilled at the rate of 60 to 90 pounds per acre, when grown for forage. It is important that they be planted no deeper than 2 inches. When grown in rows, shallow cultivation should be given until the time of blossoming. The crop is cut for hay just before the leaves fall and for seed just before the seed shatter. The hay is very palatable and nutritious, being superior to clover and oat

hay, and about equal to alfalfa. Where both crops are fairly well adapted, soy beans will produce about 35% more protein per acre than corn. When soy beans or cowpeas, however, are ensilaged alone, they develop a very unpleasant odor and become unpalatable to stock and disagreeable to handle. When they are combined with some crop containing a high proportion of carbohydrates and a low proportion of protein such as corn, sorghum, or millet, this disadvantage is avoided. The mixed silage is palatable and according to Henry, is more digestible than corn silage. It is more compact than corn silage, and it is claimed that the capacity of the silo is increased 35 to 40% by its use.

Which of these two crops to grow with corn will depend on the region and to some extent on the purpose for which the mixed crop is to be grown. Where one of them makes a markedly superior growth to the other, the question is settled. For instance, in Kansas cowpeas are recommended for every purpose over soy beans, while in Nebraska the reverse is true. In Missouri both crops are profitably grown from the northern to the southern boundary. Cowpeas make a heavier vegetative growth and are preferable all over the state for grain. *may? large? grain?* Soy beans, on the other hand, produce a heavier yield of seed and are recommended over cowpeas for a grain crop in all parts of the state. For hay, soy beans are more profitable in the northern two-thirds of the state, and the cowpeas in the southern third.

Cowpeas are very commonly grown with corn in the south and almost all of the experimental work on this problem has been done with cowpeas and corn. Soy beans, however, have some important advantages over cowpeas and where they grow well should be at least as good for mixture with corn. The soy bean produces more seed than the cowpea, and both seed and vine contain a higher percentage of protein. Its stalk grows upright without vining, making the crop easier to harvest. Soy beans are more easily cured, and seem more palatable when fed green as a pasture or soiling crop. Soy beans are commonly considered more profitable than cowpeas for both hay and seed at Columbia. A trial was therefore made of several methods of growing them with corn under field conditions. It is reported in the following pages.

EXPERIMENTAL

The original data reported in this paper were obtained from a field trial of corn and soy beans on the experiment station farm at Columbia in 1917. The object of the experiment was to determine the effect of the association on the growth, yield, and certain plant characters of corn and soy beans under actual field conditions. Eleven combinations of the two crops were grown with frequent check plots of either grown alone. The planting order included two identical series of seventeen plots each as follows:

Plot	Seeding
1	Corn drilled normal rate
2	Soy beans drilled normal rate
3	Soy beans sown broadcast in corn at corn planting
4	Soy beans sown broadcast in corn at third cultivation
5	Soy beans sown broadcast in corn at last cultivation
6	Soy beans and corn alternate in rows
7	Corn drilled normal rate
8	Soy beans drilled normal rate
9	Soy beans drilled in middles, normal rate, first cultivation
10	Soy beans drilled in middles, normal rate, third cultivation

Plot	Seeding
11	Soy beans drilled in middles, normal rate, last cultivation
12	Soy beans and corn in alternate rows
13	Corn drilled normal rate
14	Soy beans drilled normal rate
15	Corn checked $1/3$ normal rate; 2 soy beans per hill
16	Corn checked $2/3$ normal rate; 2 soy beans per hill
17	Corn checked full normal rate; 1 soy bean per hill Series duplicated and followed by soy beans drilled at normal rate (plot 35).

At the end of the second series was a check plot (No. 35) of soy beans. The corn used was of the Reid's Yellow Dent variety. The soy beans were of the Wilson variety except those planted at the last cultivation which were of the Ito San variety. The field on which the crops were grown was somewhat rolling, the soil being a fairly fertile Grundy silt loam. In 1914 oats and barley were grown on this field, in 1915 wheat, followed by cowpeas, and in 1916 soy beans.

The plots were in a single row, numbered from east to west. Each plot was $26 \frac{2}{3}$ by 136 feet, thus having an area of $1/12$ acre. In the check plots there were eight rows of corn or soy beans, forty inches apart. The corn

was planted heavily and thinned to a stand of three plants per 42 inches. The beans in the check plots were planted at the rate of twenty pounds per acre. These are considered normal seedings of corn and soy beans for the conditions of the locality. Soy beans sown broadcast were sown at the rate of 60 pounds per acre when the Wilson variety was used. Whenever the Ito San beans were sown 25% more by weight was used because of the larger seed. The seeding of corn in all plots except 12, 15, 16 and 17, and the corresponding plots in the second series, was the same as in the check plots. In plot 12 there were only four rows of corn, alternating with four rows of soy beans, or the equivalent of half a normal seeding of corn with half a normal seeding of soy beans. Plots 15, 16, and 17 were combinations of corn planted in check rows with soy beans planted in the hills, the proportions being different in the three plots.

Before planting the land was double-disked and harrowed four times. At planting time it was rather wet. The dates of important cultural operations were:

Corn planting	June 5
First cultivation (spike-tooth harrow)	June 19
Soy beans drilled in plots 9 & 26	June 22
Corn and soy beans thinned	June 23 & 25
Second cultivation (corn cultivator)	June 25
Third cultivation (spike-tooth harrow)	July 5

Soy beans drilled in plots 10 and 27; sown broadcast in plots 4 and 21	July 10
Fourth cultivation (corn cultivator)	July 12
Soy beans planted in hills thinned to required number	July 12
All plots except 9, 3, 20, and 26 hoed	July 17
Fifth cultivation (harrow)	July 31
Soy beans sown in plots 5, 11, 22 and 28	July 31
Corn harvested	Oct. 6-12
Soy beans harvested	Sept. 24 to Oct. 9

The corn in each plot was harvested when the grain was well glazed, that is, at the most favorable time of cutting for grain. All soy beans which matured seed in any considerable quantity were harvested for seed when seemingly just about to shatter the seed. In harvesting the soy beans which were planted too late to mature seed, the whole plants were pulled and weighed. In every plot the outer row on each side was discarded as a border row, leaving an area of 1/16 acre harvested in each plot. The corn shocks, husked ears, and soy bean seed were weighed in the field. The green soy bean plants and samples of fifty ears from each plot in which corn was grown were stored at a temperature of 120° F. until they reached constant weight. The moisture content of the air-dry corn stover and the oven-dry soy bean plants was determined by heating to constant weight, and that of the corn and soy

bean seed by the Brown-Duvel method. From the fifty ear samples notes were taken on the ear characters of corn grown in the different combinations, and the shelling percentage of each lot was determined. The relative size and weight of the soy bean seed from the different plots was also noted. Thus the data from the test include:

Observations on the rate of growth of corn and soy beans in each plot.

Yield of corn stover of known moisture content.

Yield of corn grain of known moisture content.

Yield of soy bean hay of known moisture content.

Yield of soy bean seed of known moisture content.

Comparative volume and weight of soy bean seed from each plot growing soy beans.

Ear characters (length, circumference, shape, indentation, and filling of butts and tips) and shelling percentage of corn from each plot growing corn.

The Rate of Growth

Beginning July 12, when differences in the appearance of the corn in different plots were first noted, five weekly measurements of the height of corn and soy bean plants in each plot were made. The plants were measured to the highest point, and the average height of plants per plot was estimated by first estimating the average for each row from measurements of fifteen to twenty representative plants. As the plants approach maturity the growth in height declines. Thus the fastest growing plots are normally the first to decline in rate of growth, and the later observations may be somewhat deceiving if this is not kept in mind.

The weekly growth determinations should give information on two important points. First they should give some idea of the variation in fertility between the plots. In a field as large as that on which this experiment was conducted it cannot be expected that the productivity of the soil will be perfectly uniform. In this field the soil was fairly uniform in appearance, but there were disturbing features in the topography. At the east end the exposure was southern; at the west end northern. The field slopes slowly downward from plot 1 to 8 and upward to 15; then after a gradual slope to the west and north extending over about 15 plots, it breaks into a distinct west slope from plot 31 to the west end. From the yields of the several

check plots we may calculate hypothetical check yields for all the plots between them on the assumption that the productivity varies regularly between check plots. Some idea of the degree of error in this assumption can be obtained from the growth determinations in the plots in which soy beans were planted late, for until the legume was planted in these plots they were exactly like the check plots. Second, these observations should show the effect of the various mixed seedings on early growth.

The height of corn plants in inches at the five weekly intervals and the weekly growth in inches are shown in the following table:

TABLE A - Growth and Height of Corn Plants in Inches

Plots	1	3	4	5	6	7	9	10	11	12	13	15	16	17
Aug. 9	81	54	84	78	82	83	76	84	87	89	89	87	88	87
Aug. 2	70	49	79	72	71	79	68	78	80	84	82	78	84	82
2-9	11	5	5	6	9	4	8	6	7	5	7	9	4	5
July 26	69	47	74	66	63	71	66	71	74	79	77	68	75	73
26-2	1	2	5	6	8	8	2	7	6	5	5	10	9	9
July 19	51	40	56	50	48.5	56	51	57.5	58.5	61	60	48	57.5	56
19-26	18	7	18	16	14.5	15	15	13.5	15.5	18	17	20	17.5	17
July 12	41	35	42	39	38	41	39	41	43	44	44.5	39	43.5	44
12-19	10	5	14	11	10.5	15	12	16.5	15.5	17	15.5	9	14	12

Plots	18	20	21	22	23	24	26	27	28	29	30	32	33	34
Aug. 9	85	65	90	87	85	87	82	90	86	87	84	85	84	78
Aug. 2	82	56	85	80	79	81	77	82	80	80	78	77	80	69
2-9	3	9	5	7	6	6	5	8	6	7	6	8	4	9
July 26	72	52	80	76	69	74	69	77	71	69	67	65	70	63
26-2	10	4	5	4	10	7	8	5	9	11	11	12	10	6
July 19	59	46	61.5	61	54	58	55	60	57	53	51	52	50	44
19-26	13	6	18.5	15	15	16	14	17	14	16	16	13	20	19
July 12	43.5	38.5	43	43.5	42	43	41.5	43	43	41	41.5	38	39	36.5
12-19	15.5	7.5	18.5	17.5	12	15	13.5	17	14	12	9.5	14	11	7.5

These growth determinations are shown in graphic form in Graphs I and III.

The corresponding determinations for soy bean plants are as follows:

TABLE B - Growth and Height of Soy Bean Plants.

Plots	2	3	6	8	12	14	15	16	17	
Aug. 16	35	29	36	38	42	40	39	36	29	
Aug. 9	31	22	34	32	35	33	32	31	26	
9-16	4	7	2	6	7	7	7	5	3	
Aug. 2	23	19	23	26	30	28	23	25	23	
2-9	8	3	11	6	5	5	9	6	3	
July 26	21.5	18	21	23	26	24.5	19	21	18	
26-2	1.5	1	2	3	4	3.5	4	4	5	
July 19	15.5	15	16	18	19	17.5	14	15.5	13	
19-26	6	3	5	5	7	7	5	5.5	5	
July 12	11	10	10	12.5	13	12	9	10	8	
12-19	4.5	5	6	6.5	6	5.5	5	5.5	5	

Plots	19	20	23	25	29	31	32	33	34	35
Aug. 16	34	32	36	34	37	37	34	36	25	36
Aug. 9	30	28	30	30	31	29	30	29	18	28
9-16	4	4	6	4	6	8	4	7	7	8
Aug. 2	23	23	22	21	22	23	22	23	16	21
2-9	7	5	6	9	9	6	8	6	2	7
July 26	19	21	17	19	19	20	18	18.5	15	18
26-2	4	2	5	2	3	3	4	4.5	1	3
July 19	15	18	13.5	14	14	14.5	12	12	10	14
19-26	4	3	3.5	5	5	5.5	6	6.5	5	4
July 12	10	13	9	11	10.5	10	9	9.5	7	9.5
12-19	5	5	4.5	3	3.5	4.5	3	2.5	3	4.5

These determinations are shown in graphic form in Graphs II and IV.

On July 12 the soy beans in plots 4, 10, 21, and 27 had been in the ground only two days and those in plots 5, 11, 22, and 28 had not yet been planted. The corn in these plots was

GRAPH I.

GRAPH II

GRAPH III

GROWTH OF CORN PLANTS

GRAPH IV

PLATE B - FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

DEPARTMENT OF ENGINEERING, UNIVERSITY OF MISSOURI

planted in the same way as the corn in the check plots, and they were therefore on that day the equivalent of check plots. If the assumption that the productivity of the land varied regularly between check plots is approximately correct the points on the graph indicating the height of the corn plants in these plots should be on or near the line connecting the points indicating the height of the corn plants in the check plots nearest them. A glance at the graph will show that they are almost on this line. The soy beans in plots 5, 11, 22, and 28 were not planted until July 31. The heights of the corn plants in these plots on July 19 and July 26 were approximately equal to the theoretical heights determined from the check plots. With the possible exception of a seeming sudden drop in productivity from plot 4 to plot 5 the fertility of the field seems to vary with fair uniformity between the check plots as far as can be determined from the early growth determinations. In the absence of a better method we may use the method of hypothetical check values in comparing the plots in this test.

As growth advanced the corn plants in plots 3 and 20 fell steadily behind the others. In these plots soy beans were sown broadcast between the rows of corn at the rate of 60 pounds per acre at planting time. As early as July 5 it was noted that the corn plants in these plots were curling their leaves and showing the lack of moisture. Throughout the experiment these plots were the first to show the effects of drought. By the middle of August the corn

leaves were very light green, and the stems were pale yellow. The only other plots in which the corn fell behind in growth to any marked extent were 9 and 26, in which soy beans were drilled in the middles at the rate of 20 pounds per acre at the time of the first cultivation. The check to the growth of the corn in these plots was not so great, but was distinct. The corn in these two plots and in plots 6 and 23, in which soy beans were sown at planting time in the row, showed the effect of drought several times during the season, though it was never severely affected.

In plots 3 and 20 the border rows of corn, which had soy beans growing on only one side, made much better growth than the inner rows, as shown by the following:

Date	TABLE C - Average Height in Inches.			
	Plot 3		Plot 20	
	Inner rows	Border rows	Inner rows	Border rows
July 12	35	39	38	42
July 19	40	49	46	57
July 26	47	61	52	71
August 2	49	64	56	76
August 16	63	76	69	84
August 23	80	86	89	93

The border rows also curled their leaves less and had a better color. In these plots the weeds soon became thick wherever the ground was not covered with soy bean plants. In the plots in which soy beans were drilled in the middles at the first cultivation the weeds also became very thick.

The soy beans planted after the third and last cultivations made very little growth. The weather at the time was dry, and when finally some of the bean plants came up the corn was high and they were in dense shade. In these

In these plots the corn was little affected by the growth of the beans, which gave a negligible yield. Most of the growth was at the ends of the rows.

The relation of temperature, rainfall, and plant growth in several typical plots is shown in Graph V. The average rate of growth in the check plots is represented by the black line. The other three lines represent the growth of corn in plots where soy beans were sown broadcast between the rows at the rate of 60 pounds per acre, where soy beans were drilled in the middles at the first cultivation at the rate of 20 pounds per acre, and where soy beans were grown in alternate rows with the corn. During the first and second week the temperature was moderate and there was some rainfall, during the third it was hot and dry, and during the fourth there were two heavy rains. In both series the plot with soy beans sown broadcast between the rows was most affected by the hot, dry weather, and the plot in which the soy beans were sown after the first cultivation was also distinctly affected, while the check plots and the plot with alternate rows of the two crops showed no effect. Corn made the best growth when planted in alternate rows with beans, both in the first series, where it led throughout the season, and in the second, where it started somewhat below the check plot and overtook and passed it. The soy beans in these plots made a slightly better growth than those in the neighboring soy bean check plot.

GRAPH V.

WEEKLY GROWTH OF CORN IN REPRESENTATIVE PLOTS

July 12 to August 9

The growth determinations indicate that when soy beans are seeded in a full stand of corn the early growth of the latter is apt to be retarded by lack of moisture under average conditions. The heavier the seeding of soy beans and the earlier in the season they are planted, the greater this effect will be. When, however, each crop is seeded at half the normal rate, in alternate rows normally spaced, the growth of the corn is better and that of the soy beans is fully as good as when they are grown separately.

Yields

Corn

The corn shocks were weighed in the field before husking, and immediately after husking the ear corn was weighed. The weight of corn stover was obtained by difference. The moisture content of the corn in the shock was determined from a sample of four typical stalks. The moisture content of the ear corn was determined from the fifty-ear samples taken from each plot for the study of ear characters. They were first dried to constant weight in a heated storage room, and the moisture content of a sample was then determined by the Brown-Duvel method.

TABLE D - Field Weights of Corn in Pounds

Plots	1	3	4	5	6	7	9	10	11	12	13	15	16	17
Shocks	610	294	582	586	562	674	424	570	602	448	730	536	662	706
Ear corn	333	54	284	293	275	343	175	275	294	223	335	244	343	369
Stover	277	240	298	293	287	331	249	295	308	225	395	292	319	337
Plots	18	20	21	22	23	24	26	27	28	29	30	32	33	34
Shocks	710	292	802	784	708	802	662	812	758	484	708	524	614	610
Ear corn	366	128	375	361	345	381	327	406	406	251	362	256	364	352
Stover	344	164	427	423	363	421	335	405	352	233	346	278	250	258

The weights in pounds of the fifty-ear samples in the field and after drying, and the weight of the shelled grain from each, are given in the following table:

TABLE E - Weight of Fifty-Ear Samples in Pounds

Plots	1	3	4	5	6	7	9	10	11	12	13	15	16	17
In field	29	10	27	27	27	33	17	22	24	35	26	34	31	29
After drying	21 $\frac{1}{4}$	7 $\frac{1}{4}$	20 $\frac{1}{2}$	20	19	23	13 $\frac{1}{4}$	17 $\frac{1}{2}$	17	26	18 $\frac{1}{2}$	24	21 $\frac{1}{2}$	20 $\frac{3}{4}$
Shelled grain	18	6	17 $\frac{1}{2}$	17	16	19 $\frac{1}{2}$	11	15	14	22	15 $\frac{1}{2}$	20	18	17 $\frac{1}{2}$

Plots	18	20	21	22	23	24	26	27	28	29	30	32	33	34
In field	31	14	29	29	31	31	31	33	34	36	33	49	38	29
After drying	22 $\frac{3}{4}$	10	20 $\frac{1}{2}$	27 $\frac{1}{4}$	23	21 $\frac{1}{2}$	22 $\frac{1}{2}$	24 $\frac{3}{4}$	24	25 $\frac{1}{2}$	25	33 $\frac{3}{4}$	29	21 $\frac{1}{4}$
Shelled grain	19 $\frac{1}{4}$	8 $\frac{1}{4}$	17 $\frac{1}{4}$	19	19 $\frac{1}{2}$	18	19	21	20	21 $\frac{1}{2}$	21	28 $\frac{1}{2}$	24 $\frac{1}{2}$	18

The shelled grain at the time this data was obtained contained 5.6% moisture. From the data given the yield of shelled corn containing 12% moisture in bushels (56 pounds) may be obtained. The yield of shelled grain, containing 12% moisture, in bushels per acre, and the yield of corn stover in tons per acre are given in the following table:

TABLE F - Corn Yields

Plot	Bushels grain per acre	Tons Stover per acre
1	63.4	2.216
3	9.9	1.920
4	56.4	2.384
5	56.5	2.344
6	49.9	2.296
7	62.1	2.648
9	34.7	1.992
10	57.4	2.360
11	52.5	2.464
12	43.0	1.800
13	61.2	3.160
15	44.0	2.336
16	61.0	2.552
17	68.2	2.696
18	69.6	2.752
20	23.1	1.312
21	68.4	3.416
22	72.5	3.584
23	66.5	2.904
24	67.8	3.368
26	61.4	2.680
27	79.1	3.240
28	73.2	2.816
29	46.0	1.864
30	70.6	2.768
32	45.6	2.224
33	71.0	2.000
34	67.5	2.064

Soy beans

In all plots in which soy beans matured seed the crop was harvested for seed and the yield of air-dry grain determined. In those plots in which the soy beans were planted too late to mature seed the crop was pulled up by the roots while still green and stored at a temperature of 100-120 degrees Fahrenheit for two months. The moisture content was then 8.5%. The weights in pounds of the soy bean crops from these plots were as follows:

TABLE G - Yields of Soy Bean Forage

Plot	Oven-Dry Matter Pounds	Dry Matter Pounds	Hay per Plot(Lbs.) 10% Moisture
5	17	15.56	17.28
11	6	5.49	6.10
21	1 $\frac{1}{4}$	1.14	1.27
22	23	21.05	23.38
28	10	9.15	10.17

As these weights include roots as well as tops, and as soy bean hay ordinarily contains less than ten per cent of moisture, it is obvious that the yield of forage from these plots was negligible. The grain yields in pounds per plot and in bushels per acre in all plots maturing soy bean seed were the following:

TABLE H - Grain Yields of Soy Beans

Plot	Pounds per Plot	Bushels per Acre (60#)
2	65.7	17.52
3	37.8	10.08
6	11.3	3.01
8	74.7	19.92
9	2.3	.61
12	44.4	11.84
14	94.8	25.28
15	21.0	5.60
16	8.6	2.29
17	3.1	.83
19	88.7	23.66
20	51.1	13.63
23	13.6	3.63
25	103.7	27.66
26	7.2	1.92
29	39.7	10.59
31	73.9	19.71
32	16.5	4.40
33	8.3	2.21
34	2.3	.61
35	80.8	21.55

TABLE I - Complete Yields of All Plots per Acre

Plot	Bu. Shelled Corn	Tons Corn Stover	Bu. Soy Bean Grain	Lb. Soy Bean Hay
1	63.4	2.216		
2			17.52	
3	9.9	1.920	10.08	
4	56.4	2.384		
5	56.5	2.344		276.48
6	49.9	2.296	3.01	
7	62.1	2.648		
8			19.92	
9	34.7	1.992	.61	
10	57.4	2.360		
11	52.5	2.464		97.60
12	43.0	1.800	11.84	
13	61.2	3.160		
14			25.28	
15	44.0	2.336	5.60	

Plot	Bu. Shelled Corn	Tons Corn Stover	Bu. Soy Bean Grain	Lb. Soy Bean Hay
16	61.0	2.552	2.29	
17	68.2	2.696	.83	
18	69.6	2.752		
19			23.66	
20	23.1	1.312	13.63	
21	68.4	3.416		20.32
22	72.5	3.388		374.08
23	66.5	2.904	3.63	
24	67.8	3.368		
25			27.66	
26	61.4	2.680	1.92	
27	79.1	3.240		
28	73.2	2.816		162.72
29	46.0	1.864	10.59	
30	70.6	2.768		
31			19.71	
32	45.6	2.224	4.40	
33	71.0	2.000	2.21	
34	67.0	2.064	.61	
35			21.55	

From the corn yields in check plots we may compute the theoretical check yield in each plot in which corn was grown, on the assumption of uniform variation between check plots. This theoretical yield may be compared with the actual yield to ascertain the effect of the seeding of soy beans in the plot.

TABLE J - Effect of Association on Corn Yield

Plot	Theoretical Check Yield Bu.per acre	Actual Yield Bu. per acre	Difference Bu.per acre	Soy bean Yield Bu.per A.
1	63.4	63.4		
3	63	9.9	-53.1	10.08
4	62.8	56.4	- 6.4	immature
5	62.5	56.5	- 6.0	"
6	62.3	49.9	-12.4	3.01
7	62.1	62.1		
9	61.8	34.7	-27.1	.61
10	61.7	57.4	- 4.3	immature
11	61.5	52.5	- 9.0	"
*12	30.7	43.0	#12.3	11.84
13	61.2	61.2		
*15	64.6	44.0	-20.6	5.60
*16	66.3	61.0	- 5.3	2.29
*17	68.0	68.2	# 0.2	.83
18	69.6	69.6		
20	69.0	23.1	-45.9	13.63
21	68.7	68.4	- 0.3	Immature
22	68.4	72.5	# 4.1	"
23	68.1	66.5	- 1.6	3.63
24	67.8	67.8		
26	68.7	61.4	- 7.3	1.92
*27	69.2	79.1	# 9.9	Immature
28	69.7	73.2	# 3.5	"
29	35.1	46.0	#10.9	10.59
30	70.6	70.6		
*32	71.1	45.6	-25.5	4.40
*33	71.5	71.9	# 0.4	2.21
*34	72.0	67.0	- 5.0	.61

*In plots 12 and 27 (soy beans and corn in alternate rows) the theoretical check yields given are half the normal because corn was planted on only half of each plot while a

normal seeding of soy beans was planted on the other half. The theoretical check yields do not apply in the plots in which corn was planted in hills, because of the difference in the manner and rate of seeding, but the check yields for drilled corn at the normal rate are given in these cases for comparison.

The disastrous effect of too heavy or too early a seeding of soy beans in a normal seeding of corn is strikingly shown in the table above. The plots in which soy beans were sown broadcast at the rate of sixty pounds per acre at corn planting time suffered an average loss of 49.5 bushels per acre in corn yield, while they produced 11.86 bushels of soy beans per acre. Where soy beans were drilled between the rows at the rate of twenty pounds per acre after the first cultivation, the average reduction in corn yield per acre was 17.2 bushels while the yield of soy beans was 1.27 bushels. Soy beans seeded in the row with the corn yielded 3.32 bushels per acre in return for a reduction in the yield of corn of 7 bushels. The growth of soy beans planted after the third and the last cultivation was too light to justify conclusions on these methods of planting. The yield of soy beans planted in the hills with checked corn was negligible, except where the seeding of corn was so far reduced as to seriously diminish the yield of corn. The only method showing a distinct and consistent gain in this test was that of planting the corn and soy beans normally in alternate rows, thus combining a half seeding of the one with a half seed-

ing of the other. While the average yield of soy beans was reduced slightly less than a bushel below half the theoretical check yield of soy beans, the average yield of corn was increased to 11.6 bushels more than half the theoretical check yield of corn for the plot, an increase of 26%. Whether due to improved space relations or to some effect of the soy beans on the corn or soil, this gain indicates promising possibilities in a method heretofore not recommended. On many Missouri farms both corn and soy beans are very profitable crops, and both are grown the same season. If they will make better growth when planted in alternate rows than when planted separately, there are few important practical objections to planting them in this way for silage or hogging off.

The failure of most of the methods tried was caused by the reduction of the water supply by the soy beans. The season was drier than usual, as shown by Graph VI. It is probable that under average Missouri conditions planting soy beans in a full stand of corn at corn planting time will reduce the yield of corn too much to be profitable, but this can be definitely determined only from the results of trials in several seasons. Any effect the soy beans may have on the supply of available nitrogen will be of no importance when moisture is the limiting factor of growth. Where both crops are grown, however, it may be found profitable to plant them in alternate rows, when this will not cause inconvenience in harvesting, for in this case the moisture supply is not reduced. The relation of the yield of corn in each plot to the theoretical check yield is shown graphically in Graph VII.

GRAPH VI

MONTHLY RAINFALL DURING GROWING SEASON AND
TOTAL ANNUAL PRECIPITATION

Monthly Annual

Precipitation

Ten inches

GRAPH VII

DEPARTMENT OF ENGINEERING, UNIVERSITY OF MISSOURI

PLATE B - FOR SALE BY THE UNIVERSITY CO-OPERATIVE STORE, COLUMBIA, MO.

YIELDS AND THEORETICAL CHECK YIELDS OF CORN.

Seed and Ear Characters

To ascertain the effect of the different treatments on the quality of the product samples of beans and ear corn from each plot were examined. The number and weight of equal volumes of beans from the plots maturing seed in the first series were determined, with the following results:

TABLE K - Soy Bean Seed Characters

Plot	Number of Seed	Weight of Seed
2	341	31.780
3	358	32.230
6	401	32.870
8	316	32.420
9	339	30.240
12	377	32.020
14	311	31.960
15	300	31.690
16	385	32.410
17	379	32.320

The variation is slight, and cannot be regarded as significant.

Fifty-ear samples from each plot were taken in the field at the time of husking, and after being stored two months in a heated room were examined as to length, circumference, shape, indentation, and filling of butts and tips. Photographs of these samples and data on ear char-

acters are given in the following pages. The scoring and placing were done by Professor C. A. Helm.

TABLE L - Summarized Ear Characters

Plot	Average Length	Average circum.	Wt.per ear at husking	Wt.per ear dry matter	Shelling per cent
1	6.4	6.22	.58	.41	84.7
3	4.9	5.03	.20	.14	82.7
4	7.0	6.16	.54	.39	85.4
5	7.2	6.16	.54	.38	85.0
6	7.0	6.13	.54	.36	84.2
7	7.5	6.38	.66	.44	84.8
9	6.3	5.47	.34	.26	83.0
10	7.0	5.91	.44	.33	85.7
11	6.9	6.16	.48	.32	82.4
12	8.5	6.50	.70	.49	84.6
13	7.3	6.16	.52	.37	83.8
15	7.9	6.41	.68	.46	83.3
16	7.6	6.22	.62	.41	83.7
17	7.5	6.22	.58	.40	84.3

TABLE M - Summarized Ear Characters (con.)

Sample No.	Uniform. of type (10)	Kernel Shape (10)	Tips (5)	Butts (5)	Placing for Show corn	Placing for Seed corn
1	5	5 $\frac{3}{4}$	2 $\frac{1}{2}$	3 $\frac{3}{4}$	2nd	2nd
3	4	1 $\frac{1}{2}$	1	1	14th	14th
4	4 $\frac{3}{4}$	6 $\frac{1}{2}$	2 $\frac{1}{2}$	3 $\frac{1}{2}$	5th	4th

Sample No.	Uniform. of type (10)	Kernel Shape (10)	Tips (5)	Butts (5)	Placing for Show corn	Placing for Seed corn
5	5	$5\frac{3}{4}$	2	$3\frac{1}{2}$	4th	5th
6	$4\frac{1}{4}$	4	$1\frac{3}{4}$	$2\frac{3}{4}$	7th	7th
7	$5\frac{1}{2}$	5	$2\frac{1}{4}$	3	3rd	1st
9	$3\frac{3}{4}$	2	$1\frac{1}{2}$	2	13th	13th
10	$4\frac{1}{2}$	$4\frac{3}{4}$	2	2	6th	6th
11	$4\frac{1}{4}$	4	$1\frac{3}{4}$	2	8th	8th
12	6	6	$2\frac{1}{2}$	$3\frac{1}{2}$	1st	3rd
13	$3\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$	11th	12th
15	$3\frac{1}{2}$	$3\frac{1}{2}$	2	$3\frac{1}{4}$	12th	11th
16	$4\frac{1}{2}$	$3\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	9th	10th
17	$4\frac{1}{2}$	3	$2\frac{1}{4}$	$3\frac{1}{2}$	10th	9th

The best method, from the standpoint of show-corn production, was the method considered best from the standpoint of yield, and the worst from the show-corn standpoint was also the worst from the yield standpoint. The ears produced when corn was grown in alternate rows with soy beans were distinctly superior in type to those produced in the check plots.

PLOT ONE

Length of Ears

Inches	5	6	7	8	9
Number of ears	7	14	24	5	

Average circumference 6.22

Average circumference 6.22 Score

Uniformity of type (10)	5
Shape of kernels (10)	5.75
Tips (5)	2.5
Butts (5)	3.75
Total (30)	17.0

Ranked second for show or seed corn.

Average weight per ear at husking	.58 lb.
Average dry matter per ear	.41
Shelling percentage	84.7%
Bushels of shelled corn (12% moisture) per A.	63.1
Tons of corn stover per acre	2.216

PLOT THREE

Length of Ears

Inches		3	4	5	6	7
Number of Ears	11	14	16	7	2	

Average circumference 5.03

Score

Uniformity of type	(10)	4
Shape of kernels	(10)	1.5
Tips	(5)	1
Butts	(5)	1
Total	(30)	7.5

Ranked fourteenth for show or seed corn.

Average weight per ear at husking	.20 lb.
Average dry matter per ear	.14
Shelling percentage	82.7
Bushels of shelled corn (12% moisture) per A.	9.9
Tons of corn stover per acre	1.920
Variation of shelled corn yield from theoretical check yield	-53.1
Bushels of soy beans per acre	10.08

PLOT FOUR

Length of Ears

Inches	4	5	6	7	8	9
Number of ears	2	9	19	15	4	1

Average circumference 6.16

Score

Uniformity of type	(10)	4.75
Shape of kernels	(10)	6.5
Tips	(5)	2.5
Butts	(5)	3.5
Total	(30)	17.25

Ranked fifth for show and fourth for seed corn.

Average weight per ear at husking	.54 lb.
Average dry matter per ear	.39
Shelling percentage	85.4
Bushels of shelled corn (12% moisture) per A.	56.3
Tons of corn stover per acre	2.384
Variation of shelled corn yield from theoretical check yield	-6.4
Bushels of soy beans per acre	immature

PLOT FIVE

Length of Ears

Inches	5	6	7	8	9	10
Number of ears	9	21	15	4	1	

Average circumference 6.16

Score

Uniformity of type	(10)	5
Shape of kernels	(10)	5.75
Tips	(5)	2
Butts	(5)	3.5
Total	(30)	16.25

Ranked fourth for show and fifth for seed corn.

Average weight per ear at husking	.54 lb.
Average dry matter per ear	.38
Shelling percentage	85.0
Bushels of shelled corn (12% moisture) per A.	56.4
Tons of corn stover per acre	2.344
Variation of shelled corn yield from theoretical check yield	-6.0
Bushels of soy beans per acre	immature

PLOT SIX

Length of Ears

Inches	-4	4	5	6	7	8	9	10
Number of ears	2	3	5	18	13	7	2	

Average circumference 6.13

Score

Uniformity of type	(10)	4.25
Shape of kernels	(10)	4
Tips	(5)	1.75
Butts	(5)	2.75
Total	(30)	12.75

Ranked seventh for show and seed corn.

Average weight per ear at husking	.54 lb.
Average dry matter per ear	.36
Shelling percentage	84.2
Bushels of shelled corn (12% moisture) per A.	49.8
Tons of corn stover per acre	2.296
Variation of shelled corn yield from theoretical check yield	-12.4
Bushels of soy beans per acre	3.01

PLOT SEVEN

Length of Ears

Inches	4	5	6	7	8	9	10
Number of ears	1	2	14	15	15	2	1

Average circumference 6.38

Score

Uniformity of type	(10)	5.5
Shape of kernels	(10)	5
Tips	(5)	2.25
Butts	(5)	3
Total	(30)	15.75

Ranked third for show and first for seed corn.

Average weight per ear at husking	.66 lb.
Average dry matter per ear	.44
Shelling percentage	84.8
Bushels of shelled corn (12% moisture) per A.	61.9
Tons of corn stover per acre	2.648

PLOT NINE

Length of Ears

Inches	-4	4	5	6	7	8	9
Number of ears	4	8	14	12	8	3	

Average circumference 5.47

Score

Uniformity of type (10)	3.75
Shape of kernels (10)	2
Tips (5)	1.5
Butts (5)	2
Total (30)	9.25

Ranked thirteenth for show and seed corn.

Average weight per ear at husking	.34 lb.
Average dry matter per ear	.26
Shelling percentage	83.0
Bushels of shelled corn (12% moisture) per A.	34.6
Tons of corn stover per acre	1.992
Variation of shelled corn yield from theoretical check yield	-27.1
Bushels of soy beans per acre	.61

PLOT TEN

Length of Ears

Inches	-4	4	5	6	7	8	9	10
Number of Ears	1	5	9	17	13	4	1	

Average circumference 5.91

Score

Uniformity of type	(10)	4.5
Shape of kernels	(10)	4.75
Tips	(5)	2
Butts	(5)	2
Total	(30)	13.25

Ranked sixth for show and seed corn.

Average weight per ear at husking	.44 lb.
Average dry matter per ear	.33
Shelling percentage	85.7
Bushels of shelled corn (12% moisture) per A.	57.3
Tons of corn stover per acre	2.360
Variation of shelled corn yield from theoretical check yield	-4.3
Bushels of soy beans per acre	immature

PLOT ELEVEN

Length of Ears

Inches	-4	4	5	6	7	8	9	10
Number of Ears	3	3	12	16	8	6	1	

Average circumference 6.16

Score

Uniformity of type (10)	4.25
Shape of kernels (10)	4
Tips (5)	1.75
Butts (5)	2
Total (30)	12.00

Ranked eighth for show and seed corn.

Average weight per ear at husking	.48 lb.
Average dry matter per ear	.32
Shelling percentage	82.4
Bushels of shelled corn (12% moisture) per A.	52.4
Tons of corn stover per acre	2.464
Variation of shelled corn yield from theoretical check yield	-9.0
Bushels of soy beans per acre	immature

PLOT TWELVE

Length of Ears

Inches	4	5	6	7	8	9	10	10 1/2
Number of Ears	1	2	7	10	20	7	3	

Average circumference 6.50

Score

Uniformity of type	(10)	6
Shape of kernels	(10)	6
Tips	(5)	2.5
Butts	(5)	3.5
Total	(30)	18.00

Ranked first for show and third for seed corn.

Average weight per ear at husking	.70 lb.
Average dry matter per ear	.49
Shelling percentage	84.6
Bushels of shelled corn (12% moisture) per A.	42.8
Tons of corn stover per acre	1.800
Variation of shelled corn yield from theoretical check yield	#12.3
Bushels of soy beans per acre	11.84

PLOT THIRTEEN

Length of Ears

Inches	-4	4	5	6	7	8	9	10	10 $\frac{1}{2}$
Number of Ears	1	1	12	14	11	6	3	1	

Average circumference 6.16

Score

Uniformity of type	(10)	3.75
Shape of kernels	(10)	2.5
Tips	(5)	1.5
Butts	(5)	2.5
Total	(30)	10.25

Ranked eleventh for show and twelfth for seed corn.

Average weight per ear at husking	.52 lb.
Average dry matter per ear	.37
Shelling percentage	83.8
Bushels of shelled corn (12% moisture) per A.	61.0
Tons of corn stover per acre	3.160

PLOT FIFTEEN

Length of Ears

Inches	-4	4	5	6	7	8	9	10	10 ¹ / ₂
Number of ears	3	5	9	1	5	13	11	3	

Average circumference 6.41

Score

Uniformity of type	(10)	3.5
Shape of kernels	(10)	3.5
Tips	(5)	2
Butts	(5)	3.25
Total	(30)	12.25

Ranked twelfth for show and eleventh for seed corn.

Average weight per ear at husking	.68 lb.
Average dry matter per ear	.46
Shelling percentage	83.3
Bushels of shelled corn (12% moisture) per A.	43.9
Tons of corn stover per acre	2.336
Variation of shelled corn yield from theoretical check yield	-20.6
Bushels of soy beans per acre	5.60

PLOT SIXTEEN

Length of Ears

Inches	-4	4	5	6	7	8	9	10	10 $\frac{1}{2}$
Number of ears		3	4	9	7	9	6	7	5
Average circumference			6.22						

Score

Uniformity of type	(10)	4.5
Shape of kernels	(10)	3.75
Tips	(5)	2.25
Butts	(5)	2.75
Total	(30)	13.25

Ranked ninth for show and tenth for seed corn.

Average weight per ear at husking	.62 lb.
Average dry matter per ear	.41
Shelling percentage	83.7
Bushels of shelled corn (12% moisture) per A.	60.9
Tons of corn stover per acre	2.552
Variation of shelled corn yield from theoretical check yield	-5.3
Bushels of soy beans per acre	2.29

PLOT SEVENTEEN

Length of Ears

Inches	-4	4	5	6	7	8	9	10	10 $\frac{1}{2}$
Number of ears	1	2	12	10	13	7	4	1	

Average circumference 6.22

Score

Uniformity of type	(10)	4.5
Shape of kernels	(10)	3
Tips	(5)	2.25
Butts	(5)	3.5
Total	(30)	13.25

Ranked tenth for show and ninth for seed corn.

Average weight per ear at husking	.58 lb.
Average dry matter per ear	.40
Shelling percentage	84.3
Bushels of shelled corn (12% moisture) per A	68.0
Tons of corn stover per acre	2.696
Variation of shelled corn yield from theoretical check yield	#0.2
Bushels of soy beans per acre	.83

Summary and Conclusions

This paper reports the results of a trial of soy beans grown with corn in the following ways: (1) planted with corn, both crops at a full normal rate, (2) planted with corn, both at half the normal rate, (3) planted at a low rate in the row with a full stand of corn, and (4) planted in a full stand of corn at various rates after it had received one or more cultivations. In a season more favorable than the average for the locality, it was found that soy beans planted at a high or low rate with a full seeding of corn (1) and (3) delayed the growth of the latter by depriving it of moisture, greatly reduced its yield, and affected unfavorably the quality of the ear corn produced by it. Soy beans planted in a full stand of corn after it had received one cultivation (4) reduced the yield and quality of corn considerably, without producing a seed yield of consequence, while soy beans planted after three or more cultivations made practically no growth. When soy beans and corn were planted together, each at half the normal rate (4), the yield and quality of the individual corn plants were distinctly improved, while the soy beans yielded normally. The unfavorable results of the addition of soy beans to a full stand of corn seem due to their effect on the moisture supply, which they reduce not only by their own use of moisture, but in many cases, by their interference with cultivation. In a season with somewhat more moisture than was present in that of 1917, it is possible

that the planting of soy beans in corn after one or more cultivations may be found profitable. The failure of the soy bean crop in plots so planted in this test was undoubtedly caused in large part by the dry conditions at the time of soy bean planting.

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